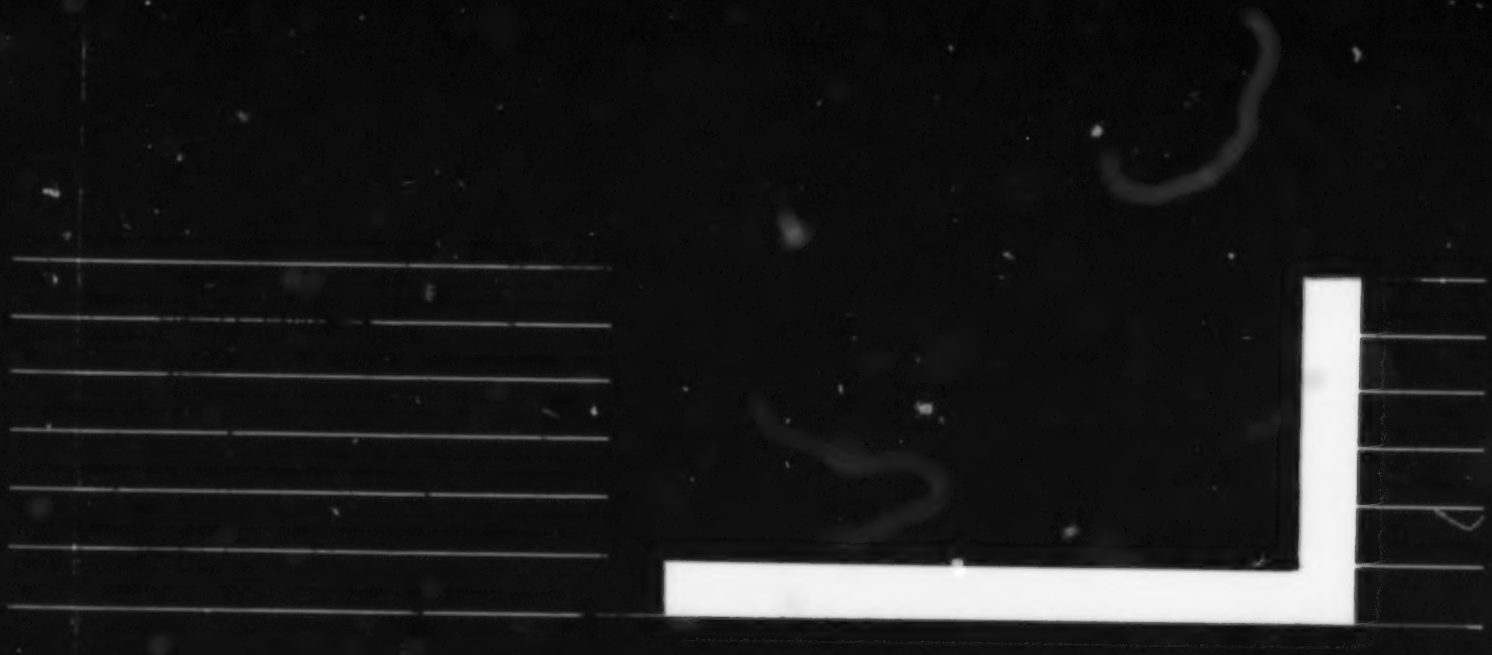
Bureau canadien
de la sécurité aérienne

Canadian Aviation
Safety Board



Canada

The Canadian Aviation Safety Board investigated this occurrence for the purpose of advancing aviation safety. It is not the object of the Board to determine or apportion any blame or liability.

AVIATION OCCURRENCE REPORT

NORTHLAND AIR MANITOBA LTD
DOUGLAS DC-3C C-FADD
PICKLE LAKE, ONTARIO 2 mi W
11 MAY 1987

REPORT NUMBER 87-C70022

SYNOPSIS

The aircraft had completed a cargo flight, and, on return to the Pickle Lake Airport, Ontario, the crew decided to carry out local flight training. Following holding procedures, an instrument approach was initiated. Shortly thereafter, the aircraft was seen in a steep dive with the left wing folded upwards beyond 90 degrees. The descent continued until the aircraft struck the ground approximately two miles northwest of the airfield. The aircraft was destroyed, and the two occupants were fatally injured.

The Canadian Aviation Safety Board determined that the left wing failed under normal flight loads as a result of a fatigue crack in the centre section lower wing skin. Anomalies in the radiographs taken during mandatory non-destructive testing inspections were not correctly interpreted.

Ce rapport est également disponible en français.

15 February 1989

TABLE OF CONTENTS

		Page
1.0	**FACTUAL INFORMATION**	1
1.1	History of the Flight	1
1.2	Injuries to Persons	2
1.3	Damage to Aircraft	2
1.4	Other Damage	2
1.5	Personnel Information	2
1.6	Aircraft Information	3
1.6.1	General	3
1.6.2	Wing-Inspection Information	3
1.7	Meteorological Information	5
1.8	Aids to Navigation	5
1.9	Communications	5
1.10	Aerodrome Information	5
1.11	Flight Recorders	5
1.12	Wreckage and Impact Information	6
1.13	Medical Information	6
1.14	Fire	6
1.15	Survival Aspects	6
1.16	Tests and Research	7
1.16.1	Exhaust Stack Analysis	7
1.16.2	Examination of the Left Wing	7
1.16.3	Examination of the Radiographs	8
1.16.4	Inspection Report Dated 25 February 1980	9
1.17	Additional Information	9
1.17.1	Flight Profile	9
1.17.2	Aircraft Structures Radiography	9
2.0	**ANALYSIS**	11
2.1	Introduction	11
2.2	History and Use of the Aircraft	11
2.3	In-Flight Overload	11
2.4	Wing-Failure Analysis	12
2.5	Wing-Inspection Analysis	12
2.6	Review of SB 263	13
2.7	Regulations - A/S Radiography	13
2.8	NDT Certification	14
3.0	**CONCLUSIONS**	15
3.1	Findings	15
3.2	Causes	16

4.0	**SAFETY ACTION**	17
4.1	Action Taken	17
4.1.1	Audit of NDT Facility	17
4.1.2	DC-3 Wing Structural Integrity	17
4.1.3	Clarification of SB 263	17
4.1.4	Regulatory Control of NDT Radiography for Aircraft Structures	18
4.2	Further Action Required	19
4.2.1	Non-Destructive Testing - Independent Checks	19
5.0	**APPENDICES**	
	APPENDIX A - AREA MAP AND FLIGHT PATH	A-1
	APPENDIX B - WING CENTRE SECTION	B-1
	APPENDIX C - WING FRACTURE	C-1
	APPENDIX D - LABORATORY REPORTS	D-1
	APPENDIX E - GLOSSARY	E-1

1.0 FACTUAL INFORMATION

1.1 History of the Flight

On 11 May 1987, a Douglas DC-3C, C-FADD, was returning to Pickle Lake from Big Trout Lake, Ontario, following delivery of a cargo of fuel. This was the third similar and last operation of the day. The flight was being conducted under visual flight rules (VFR)* and the two pilots were the sole occupants on board. As the aircraft approached Pickle Lake, the pilot informed the company dispatch office that, prior to landing, he intended to carry out some local training for the benefit of the co-pilot who was scheduled to be upgraded to captain status the following month. The captain, a company training pilot, occupied the right seat.

The aircraft entered a west to east holding pattern at the airport's non-directional beacon (NDB), descending in stages from 8,500 feet above sea level (asl) to 2,700 feet asl, the appropriate altitude for an instrument approach. The pilot transmitted that they would execute an NDB approach and subsequently reported during the procedure turn inbound to the airfield. About three minutes later, two other pilots flying in the vicinity observed the aircraft in a descent with the left wing folded upwards. The aircraft continued descending in an inverted attitude until it struck the ground (see Appendix A).

The accident occurred two miles west of Pickle Lake at 1800 central daylight time (CDT)** during the hours of daylight, at lat 51°28'N, long 90°13'W*** at an elevation of about 1,215 feet asl.

* See Glossary for all abbreviations and acronyms.

** All times are CDT (Coordinated Universal Time (UTC) minus five hours) unless otherwise stated.

*** Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	2	-	-	2
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	2	-	-	2

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

	Pilot-In-Command	Co-Pilot
Age	38	33
Pilot Licence	Airline Transport	Airline Transport
Medical Expiry Date	28/04/88	10/09/87
Total Flying Time	9,130 hr	5,169 hr
Total on Type	5,500 hr	2,795 hr
Total Last 90 Days	224 hr	278 hr
Total on Type Last 90 Days	224 hr	278 hr
Hours on Duty Prior to Occurrence	11 hr	11 hr
Hours off Duty Prior to Work Period	41 hr	41 hr

Both pilots held valid licences and were qualified to conduct the flight. The pilot-in-command was a company training pilot and occupied the right seat. The co-pilot was receiving training in preparation for upgrading to captaincy status and was probably at the controls.

1.6 Aircraft Information

1.6.1 General

Manufacturer	Douglas Aircraft Company
Type	DC-3C
Year of Manufacture	1944
Serial Number	26324
Certificate of Airworthiness	Valid
Total Airframe Time	20,284 hr
Engine Type (2)	Pratt & Whitney R1830-92
Propeller Type (2)	Hamilton Standard 23E50-473
Maximum Allowable Take-off Weight	26,900 lb
Recommended Fuel Types	100/130

The aircraft was manufactured by the Douglas Aircraft Company as a model R4D-6 and delivered to the United States Navy in 1944. It was imported into Canada in 1973 with 7,587.39 hours total airframe time. At the time of the accident, it had accumulated a total of 20,283.7 hours, all on wheel landing gear. The aircraft was operated by the same company, albeit with a name change, since importation.

The aircraft was used principally in supply operations to northern communities. The total airframe time was less than other aircraft of similar vintage because of the low time accumulated prior to 1973.

There was no record of hard landings or flight through turbulence conditions that warranted an inspection. The weight and centre of gravity were within the prescribed limits. The aircraft was certified, equipped, and maintained in accordance with existing procedures, except for anomalies noted in associated non-destructive testing (NDT) inspections.

1.6.2 Wing-Inspection Information

As a result of identified DC-3 wing cracking problems, McDonnell Douglas had issued Service Bulletin No. 263 (SB 263) dated 23 February 1966. There have since been eight revisions with the latest dated 15 December 1971. SB 263 requires radiographic inspection of the front spar and the wing bottom skin at stations 127.750 and 94.250 on both sides of the wing centre section (see Appendix B). For each wing, four views are taken from two different angles along both wing stations, using double-loaded film. A complete inspection results in

the production of 32 negatives, or two sets of 16 which are labelled P1 to P8 for the aircraft left side, and S1 to S8 for the right side. If a crack is identified during the inspection, a repair doubler reinforcement is required. SB 263 also makes provision for the installation of the doubler on an optional basis. If the doubler is installed, the radiographic reinspection cycle is set at 2,000 hours. If the doubler is not fitted, the inspection interval is 900 hours. The accident aircraft had not been fitted with the doublers and was subject to the 900-hour inspection cycle.

If an aircraft is not fitted with the doublers, SB 263 stipulates that, along with the radiographic inspection, a visual and dye-penetrant examination must be carried out every 900 hours for all accessible portions of the front spar web, from inboard of station 94.250 to outboard of station 127.50. This also includes the exposed lower wing skin along the front spar for a distance of approximately eight inches aft of the spar cap. Compliance with the requirements of SB 263 is made mandatory by Airworthiness Directive Number 69-15-04.

The Technical Log Book showed that the radiographic inspection had been carried out at all previous required intervals while the aircraft was registered in Canada, with the latest dated 23 November 1986. The inspections were carried out with the landing gear down or with the aircraft on jacks. No discrepancies pertaining to these inspections were recorded in the technical log sheets. All the inspections were carried out by the same individual, except for an inspection which was performed on 25 February 1980.

There were no indications that the dye-penetrant check was carried out on the aircraft. The company engineer believed that this inspection was the responsibility of the NDT company contracted to fulfill the requirements of SB 263. On the other hand, the NDT radiographer was only completing the radiographic portion of SB 263. In the course of the investigation, it became apparent that the SB 263 dye-penetrant check was seldom completed on this or other DC-3s.

SB 263 was reviewed for completeness and clarity. The bulletin was found to be open to misinterpretation with respect to the number of radiographs required, their positions, and the radioactive source placement for some shots. For example, Figure 1, Sheet 2 of the bulletin indicates 12 locations requiring radiographic examination, but only four x-ray tube positions are shown.

It was noted some radiographers did not have, or were not using, the latest revision of SB 263. In one case, revision number one, which varies considerably from the latest edition, was still being applied. It is not clear who is responsible for ensuring that the latest revision has been received - the company responsible for maintenance or the company responsible for executing the requirements of SB 263. There was no system in place whereby Transport Canada could verify that the latest version of SB 263 was being applied by the radiographer.

1.7 Meteorological Information

Visual meteorological conditions prevailed with scattered clouds based at 2,800 feet above ground level (agl). The visibility was 15 miles, and the surface winds were blowing from 350 degrees magnetic at eight knots. Pilots flying in the area reported that only light turbulence existed.

1.8 Aids to Navigation

The NDB is the sole aid to navigation at Pickle Lake, and it was being utilized by the aircraft for training purposes. The NDB was serviceable and operating before and after the accident.

1.9 Communications

Very high frequency (VHF) communications were well established between the aircraft and the appropriate air traffic information agency. Normal transmissions were received from the aircraft giving no indication of difficulty.

1.10 Aerodrome Information

The Pickle Lake Airport is a publicly licensed aerodrome operated by the Government of Ontario. All services were operating satisfactorily.

1.11 Flight Recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

The aircraft struck the muskeg surface while in an inverted attitude, at a descent angle of approximately 70 degrees. The wreckage trail was forward of the point of impact to a distance of about 150 feet, and the direction was oriented on a heading of 080 degrees magnetic. The nose and fuselage sections sustained massive damage. The badly damaged right wing was still attached to the centre section. The tail assembly had twisted sharply but was relatively intact. The landing gear and the flaps were retracted.

Both engines were torn from their mounts. The propellers were twisted and bent in a manner indicative that the engines were delivering power at impact. Propeller paint marks were found on six-inch diameter trees which had been cleanly severed. The control systems were examined, to the extent possible, and no evidence of pre-impact failure was found. The positions of the elevator, aileron, and rudder trims were consistent with a normal flight profile.

The left wing, located approximately 650 feet to the west of the main wreckage, had landed flat and had sustained very little damage. The wing had fractured inboard of the wing joint (see Appendix B).

1.13 Medical Information

There was no evidence that incapacitation, physiological, or psychological factors affected the crew's performance.

1.14 Fire

There was no evidence of fire either before or after the occurrence.

1.15 Survival Aspects

The accident was not survivable due to the magnitude of the deceleration forces.

1.16 Tests and Research

1.16.1 Exhaust Stack Analysis

A section of the damaged exhaust collector tube, with the riser attached, was recovered from each engine and forwarded to the CASB Engineering Laboratory for metallurgical analysis. The components were examined to determine whether they were hot or cold at the time of damage. The examination of the crushed sections indicated that the exhaust stack material was at normal operating temperature at impact.

1.16.2 Examination of the Left Wing

The left wing centre section, containing the lower skin fracture, together with the lower skin pieces having the mating fractures were analysed at the CASB Engineering Laboratory (see Appendix C).

The fracture of the bottom skin extended from the front spar in the vicinity of station 127.750, aft through to the centre spar, a distance of approximately 35 inches. The crack line followed approximately the inboard rib flange rivet line. The centre section wing stringers, numbered 58 to 65, were also fractured in this area. The separation line then travelled outboard to the attachment angle at wing station 142.0 as a result of overload shearing of the centre spar and lower skin fasteners. The centre section attachment angle doublers, between the centre and rear spars, then failed along the inboard most rivet line where the doublers connect to the attachment angle. The failure of the bottom skin at the trailing edge assembly completed the bottom surface failure. The wing's upper skin extending from the leading edge to the rear spar, failed in overload bending and tearing. The wing attachment bolts on the trailing edge assembly failed in tension. No previous damage repairs appeared to have been done in the area where the failure occurred.

The centre section lower wing skin had separated from the front spar, and all the fasteners were missing, except for the outboard bolt fastener. Examination of these spar fastener holes showed them to be relatively clean and without any indications of severe distress such as hole deformation due to fastener pull-out, or overload shearing. In particular, the four bolt fasteners at the bottom outboard end of the front spar, where the jacking pad is mounted, were also missing, and the holes did not show any signs of deformation. The mating section of the front spar from this area had remained with the main wreckage upon wing separation.

1.16.3 Examination of the Radiographs

Two sets of radiographs were obtained from the radiologist who had been retained by the operator to carry out the SB 263 inspection. The sets were contained in dated envelopes.

The first set, reportedly taken in October 1986, was identified by aircraft registration and film position only. Two of the radiographs were identified as being from another DC-3 aircraft, and two were reported as being from an inspection carried out in January 1986. The second set, similarly labelled, was reported as being taken in January 1986. Individual radiographs were not dated, and it was impossible to relate them to a specific inspection. According to the Technical Log Book, inspections were carried out on 19 January 1986 and 23 November 1986. At the latter inspection, which occurred 297.8 hours before the accident, the aircraft had accrued a total of 19,985.9 hours.

The negatives were examined at the CASB Engineering Laboratory and by specialists from private industry.

During the examination of negative P4, reported to be from the 23 November 1986 inspection, no cracks were noted. However, negative P4, belonging to the set of radiographs dated January 1986, revealed a large skin crack approximately 15 inches in length which extended predominantly along the inboard flange rivet line. This crack line matched exactly the actual crack path on the failed wing.

Negative P1, from both sets, revealed similar crack indications. One appeared in the lower wing skin through a front spar fastener hole and another in the lower spar strap through an adjacent front spar fastener hole. On both negatives, the location of the crack indications matched the actual crack path found on the failed wing. Also, one of the P1 negatives revealed that the head and most of the bolt shank were missing on three bolt fasteners in the vicinity of station 127.50. It also revealed that an adjacent rivet was missing. The missing fasteners could readily be detected during a visual inspection associated with SB 263, or any other periodic inspection.

The certified Level II radiographer who took the radiographs and who operated as a one-man company provided the operator with an inspection form which stated that there were no apparent defects. The radiographer retained the negatives on his company files.

1.16.4 Inspection Report Dated 25 February 1980

A report dated 25 February 1980, prepared by another NDT company, covering the SB 263 inspection carried out on 20 February 1980, was submitted to the aircraft operator. The report states "....station 127.750, x-ray view No.3, exhibits a 1 1/2 inch crack indication in lower skin/flange on inboard side just aft of front spar. Crack extends through at least two rivet holes and does not appear to have been previously repaired." The operator's technical personnel, who carried out a visual inspection, could not find any evidence of a crack and signed the Technical Log Book, indicating that the radiographic inspection was carried out. Subsequent inspection reports, submitted by a different NDT company, reported no apparent defects.

1.17 Additional Information

1.17.1 Flight Profile

The diagram at Appendix A depicts the most probable flight path.

The captain had reported the procedure turn inbound in a voice transmission that was similar in tone to all others made by him previously. The transmissions, including the last, were given in a calm manner and were completely devoid of any indication of stress.

1.17.2 Aircraft Structures Radiography

The radiographic NDT method is one of a number of techniques used to carry out NDT inspections of aircraft structures. The advantages of radiography are that internal or covered structures can be examined for defects, as well as areas that are difficult to access. A further advantage is that a permanent inspection record is available for retention. NDT radiography is used for the DC-3 SB263 inspection because it is the most suitable, given the inaccessibility of the area and the layered construction encountered.

However, radiography has its disadvantages. The method is directional in nature, and correct film placement and radioactive source are essential to the process. Further, interpretation of the results depends on the training, experience, judgement, and skill of the radiographer. The method is not infallible and differing interpretations of the radiographs are possible.

The certification of NDT radiographic personnel is the responsibility of the Department of Energy, Mines and Resources (EMR). Since 1979, the Canadian General Standards Board (CGSB) Committee on Certification of NDT Personnel has been responsible for all the standards for the certification of NDT personnel. The 1978 edition of 48-GP-4M - Standard for Certification of Nondestructive Personnel (Industrial Radiography Method) was developed by the CGSB Committee on Industrial Radiography and the Subcommittee on Certification Radiographic Personnel. The latest issue of 48-GP-4M is dated October 1978, and the latest published amendment is dated July 1987. Transport Canada was represented on the committee which developed the 1978 edition, is represented on the current Committee on Certification of NDT Personnel, but is not represented on the current Committee on NDT - Industrial Radiography. Transport Canada has accepted 48-GP-4M as the standard for certification.

There are three levels of certification: Level I personnel conduct radiography under supervision; Level II personnel do not require supervision; and Level III personnel are qualified to supervise. Levels II and III are split into a General Category and an Aircraft Structures Category (A/S).

Once an individual is certified to Level II, he is permitted to conduct radiographic work on aircraft without supervision or a further need to demonstrate competency. Previous to January 1987, an annual eye test was required to hold a certificate, but this has been changed to a three-year requirement. Recertification may be required when a certified person is not employed in radiography for a continuous period of one year or more.

The requirements of 48-GP-4M state that radiographic personnel must be competent in maintaining accurate records. Precise requirements for identification of radiographs are not stipulated; the labelling of radiographs is left to the discretion of the NDT company, the individual radiographer, or the agency contracting the work. The lack of suitable identification on the radiographs in question impeded the course of the investigation.

The ownership of the radiographs is also open to question, with some believing they are the property of the radiographer and others the property of the contracting company. As well, there is no requirement to retain radiographs for any period of time following the inspection.

2.0 ANALYSIS

2.1 Introduction

The obvious separation of the left wing prompted investigation into a number of areas. The history of the aircraft and its use were examined. The possibility that the aircraft was subjected to in-flight overloads was also examined. The wing inspection documents and practices underwent detailed scrutiny, as did the process of aircraft structures radiography and the associated controls and standards.

2.2 History and Use of the Aircraft

The aircraft was imported into Canada in 1973 and was then flown at a rate of approximately 1,000 hours per year. This type of aircraft is used principally in passenger and cargo operations to northern Canadian communities. It is one of aviation's legendary machines, and it is known as a "workhorse" aircraft.

Operations from rough northern airstrips place a greater degree of wear on aircraft than those operating from paved runways. However, there was no evidence to indicate that the aircraft had experienced greater or less wear than other aircraft operating in a similar environment. There were no recorded instances of hard landings or flight through turbulence that could be considered contributory to the accident.

2.3 In-Flight Overload

The lightly loaded aircraft was well within the weight and centre of gravity limitations and was being flown for local instrument training purposes in good weather conditions. The pilot had transmitted his intentions and followed them precisely. There was no evidence of flight crew incapacitation, and the possibility of the pilot overstressing the aircraft has been discounted.

The weight of evidence from examination of the wreckage and the laboratory analysis of the exhaust stacks leads to the conclusion that the engines were producing power at impact. The flight control system was examined, and no deficiencies were found. The trim positions were consistent with the flight profile being flown. Based on the result of these findings, it was concluded that an aircraft system malfunction did not precipitate an in-flight overload condition.

The wing failure occurred while the aircraft was being operated in normal flight conditions with all the necessary systems functioning satisfactorily.

2.4 Wing-Failure Analysis

Laboratory tests revealed that the left wing separated from the aircraft as a result of extensive fatigue cracking in the lower skin of the wing centre section in the vicinity of wing station 127.750. Analysis of the crack indicated that the fatigue probably initiated at the second rivet hole aft of the edge of the skin adjacent to the front spar. The crack then propagated forward to the edge of the skin and aft to the centre spar, following the inboard rib flange rivet line for most of its length. The cracking of the skin was considered to be very high-cycle fatigue in nature, occurring over an extended period of flying time.

While the crack progressed through the skin, more and more of the wing loads were transferred to the stringers and to the front spar through the fasteners. The absence of the lower front spar fasteners outboard of station 127.750 and the relatively clean, undamaged condition of the fastener holes indicated that these fasteners had also failed progressively, prior to separation of the wing. The observed fatigue fracture of the most outboard fastener supports this assessed sequence of failure. The lower cycle nature of the crack propagation in the stringers indicated that the stringer failures occurred during the later stages of the wing failure.

2.5 Wing-Inspection Analysis

The NDT specialists who examined the radiographs concluded that both the missing fasteners and the skin crack were detectable to a qualified radiographer.

The success of radiography is highly dependent on the judgement, skill, and thoroughness of the individual radiographer. In other areas of aviation maintenance, where critical functions require similar subjective interpretations, it is common practice for work to be examined by more than one person. There is no such requirement for radiography.

The apparent widespread omission of the dye-penetrant portion of SB 263 is another symptom of the lack of monitoring of NDT procedures. Given the location of the crack in C-FADD, it is unlikely that the dye-penetrant check would have confirmed the crack

detected by radiography; however, a degree of hazard is introduced when any portion of a mandatory safety inspection procedure is omitted.

A 1 1/2 inch crack indication at station 127.750 had been reported to the operator in 1980 by a different radiographer. However, according to the operator, the crack indication could not be confirmed following a visual inspection.

Had a thorough visual inspection been completed following the radiographic inspection of 23 November 1986, or any subsequent periodic inspection, the missing fasteners in the vicinity of station 127.750 identified on the radiographs would have been detected, even though the radiographer who had performed all the inspections except for the one in 1980 had advised the operator that there were no apparent defects. The bulletin required that a repair doubler be installed for any crack detected and confirmed. There are no documented cases of wing failures on aircraft equipped with the doubler.

2.6 Review of SB 263

The degree of ambiguity noted in the directions contained in SB 263 could lead to incorrect placement of the radiographic film and the radioactive source. This would result in incomplete coverage of the area to be inspected.

There have been eight revisions to SB 263, but some radiographers continue to use older versions. This stems from an inadequate distribution system and a weakness in surveillance.

2.7 Regulations - A/S Radiography

The radiographic standards published in 48-GP-4M state that radiographers must maintain accurate records; there is no further amplification. None of the individual radiographs obtained in the course of the investigation was dated, and two were not labelled in any way. The correct identification of radiographs is essential to the overall process.

Document 48-GP-4M does not state a period of time over which radiographs must be retained. The radiographs could be destroyed immediately following examination, and one of the advantages of radiography, a permanent record, would be lost. Without such records, monitoring by a regulatory agency would be impossible.

2.8 NDT Certification

Transport Canada's involvement in NDT certification is limited to membership in the NDT Standards Committees and does not extend to monitoring compliance with the standards established. This situation falls below the standard maintained by Transport Canada regarding other aviation-related maintenance activities such as engine overhauls.

3.0 CONCLUSIONS

3.1 Findings

1. The left wing failed in flight, under normal flight loads, as a result of a fatigue crack in the centre section lower wing skin in the vicinity of station 127.750.

2. A 15-inch fatigue crack was visible in radiographs taken at the normal inspection cycle, 297.8 hours of flight time before the accident, but was not interpreted by the radiographer.

3. Had a thorough visual inspection been completed following the radiographic inspection of 23 November 1986 or during subsequent periodic inspections, the missing fasteners would have been detected.

4. All the radiographic examination reports, except for the one performed by a different company on 25 February 1980, stated that there were no apparent defects.

5. The radiographs taken at the normal inspection cycle, 297.8 hours of flight time before the accident, showed that three bolt fasteners and an adjacent rivet were missing from the bottom of the front spar in the vicinity of station 127.750.

6. The visual inspection done by the operator following an inspection report dated 25 February 1980 which stated there was a crack indication at station 127.750 was not documented in the aircraft log books.

7. The requirement of SB 263 to conduct a dye-penetrant check in conjunction with the radiographic inspection was not fulfilled on this aircraft and on some other DC-3s operating in Canada.

8. Although SB 263 is ambiguous with respect to the placement of the radiographic film and the radiographic source, misinterpretation of SB 263 was not a factor in the accident.

9. Outdated versions of SB 263 are used by some radiographers.

10. The work of certified radiographers is not supervised or audited to the standard existing in other areas of aviation maintenance.

11. There are no aviation regulatory standards applicable to radiographic work performed on aircraft.

12. There were no recorded instances of hard landings or flight through turbulence that could be considered contributory to the accident.

13. An aircraft system malfunction did not precipitate an in-flight overload condition.

14. The structural failure was not the result of pilot-induced manoeuvres.

15. The flight crew was certified and qualified for the flight in accordance with existing regulations.

16. The aircraft was certified and equipped in accordance with existing regulations and approved procedures.

17. The weight and centre of gravity were within the prescribed limits.

3.2 Causes

The left wing failed, under normal flight loads, as a result of a fatigue crack in the centre section lower wing skin. Anomalies in the radiographs taken during mandatory non-destructive testing inspections were not correctly interpreted.

4.0 SAFETY ACTION

4.1 Action Taken

4.1.1 Audit of NDT Facility

Early in the investigation, it became evident that, with respect to the facility that had conducted the non-destructive testing (NDT) of DC-3 registration C-FADD, several anomalies existed regarding radiographic techniques and the interpretation of radiographs. Indications of cracks and missing fasteners, clearly evident on the radiographs, did not appear to have been interpreted as such. Consequently, the Canadian Aviation Safety Board issued an Interim Recommendation, on 10 June 1987, recommending that:

> The Department of Transport initiate an immediate and complete audit of the NDT inspections, regardless of aircraft type, conducted by the company which carried out the recent X-ray inspections of the DC-3 aircraft, registration C-FADD.
>
> CASB 87-15

In response, Transport Canada conducted an audit of all NDT inspections performed by the company responsible for the radiographic inspections of C-FADD. In cases where the necessary records could not be traced for any particular aircraft, the required inspections were repeated.

4.1.2 DC-3 Wing Structural Integrity

To further ensure the structural integrity of the wings of all Canadian-registered DC-3s, Transport Canada issued Emergency Airworthiness Directive (AD) CF-87-06 Douglas, effective 05 June 1987. The AD called for a review of the latest radiographs and aircraft technical records by qualified personnel; the repeat of Service Bulletin (SB) 263 if deemed necessary; and the incorporation of a wing skin doubler within 900 flight hours, 12 months, or the next wing removal, whichever occurred first.

4.1.3 Clarification of SB 263

As a matter of policy, the McDonnell-Douglas Corporation no longer issues service bulletins for their older aircraft; instead, they communicate any revised work instructions for these aircraft via

service rework drawings. With respect to the DC-3, McDonnell-Douglas has now issued four rework drawings which provide revised inspection and modification data for compliance with SB 263. The drawings are more detailed than the original SB 263 (and revisions): they provide inspection area and access illustrations, radiographic film requirements, film-cutting instructions, radiographic source locations, and film placement and exposure data. In addition, the revised procedures specify a more detailed visual inspection and a radiographic inspection that includes the need for proper identification.

4.1.4 Regulatory Control of NDT Radiography for Aircraft Structures

Following this accident, Transport Canada conducted a study of the present NDT situation throughout the industry in Canada. This study identified three major problems with the current Transport Canada policy. Their report recommended that the Canadian General Standards Board (CGSB) and MIL-STD-410 standards for the qualification and certification of NDT personnel be recognized as airworthiness standards and that the certification and release of NDT be done under Transport Canada company maintenance approval. This system would be applicable to all personnel performing and certifying NDT in the civil aviation industry, including manufacturing and maintenance organizations as well as aircraft maintenance engineers. In addition, the report recommended changes to the Transport Canada Curriculum Guide for the training of aircraft maintenance students on NDT knowledge, techniques, and applications; it also recommended increased Transport Canada surveillance of institutions accredited to teach this material. It is understood that these recommendations have been accepted and are currently being implemented.

Transport Canada is to be commended for their comprehensive follow-up to this occurrence. Full implementation of the Transport Canada study's recommendations will go a long way toward precluding a recurrence of the circumstances which led to this accident.

4.2 Further Action Required

4.2.1 Non-Destructive Testing - Independent Checks

In the aircraft industry, almost all work is checked, tested, or supervised at various stages. In this occurrence, the individual performing the NDT, although certified to Level II, did the radiographic work without supervision, and the resulting radiographs were interpreted by him alone. Seeking a second opinion of a person qualified to interpret the radiographs taken of the wings of C-FADD would have increased the probability of detecting the anomalies extant.

According to N-AME-AO 12/84, "Standards For the Certification Of Nondestructive Testing Personnel", Level II or III CGSB certified NDT personnel are permitted to certify NDT work performed, and the airworthiness certification of the aircraft is then accomplished by an aircraft maintenance engineer (AME) endorsed in the appropriate category. However, many AMEs do not have the qualifications necessary to carry out NDT, nor are they capable of making valid judgments on the techniques of work performed by outside contracted agencies. Thus, the signature of the AME in certifying the airworthiness of the aircraft can often be a formality rather than a legitimate second opinion or "supervision" of the NDT work.

Supervisory personnel certifying the airworthiness of NDT work must be qualified in the NDT technique being performed in order to provide any credible second opinion. Since the interpretation of NDT results (particularly radiographic results) often requires the judgement gained through experience, knowledge and experience in the techniques used is required.

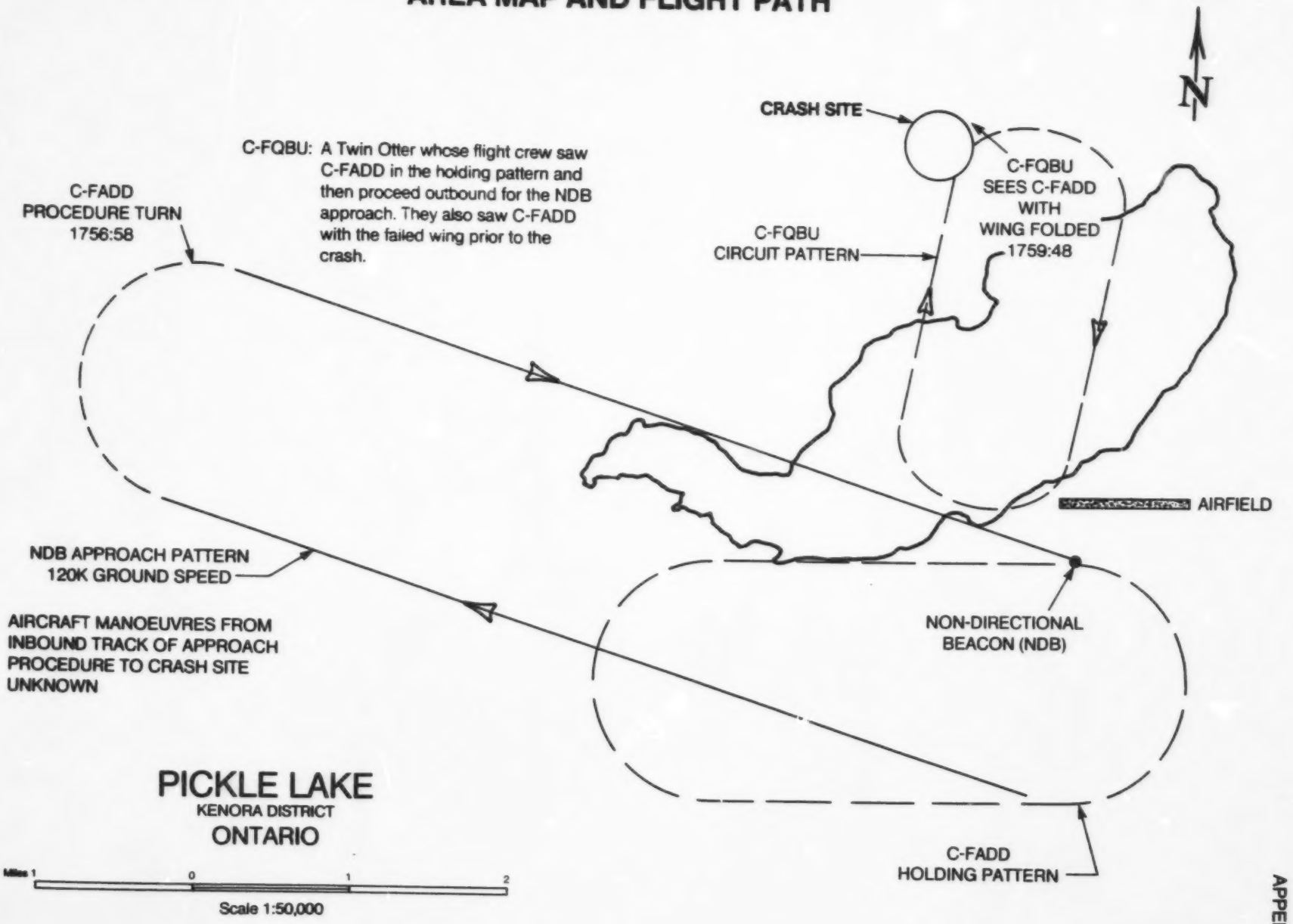
At present, the Transport Canada Airworthiness Manual (Chapter 571.209) requires an independent check of control systems "where any maintenance disturbs a system by which the flight altitude or propulsive force of an aircraft is controlled." This occurrence demonstrates that mandatory radiographic testing of critical aircraft components also requires an independent check by a qualified person. Therefore the CASB recommends that:

> The Department of Transport develop procedures for conducting an independent check by a qualified person of the results of any mandatory radiographic testing of critical aircraft components.

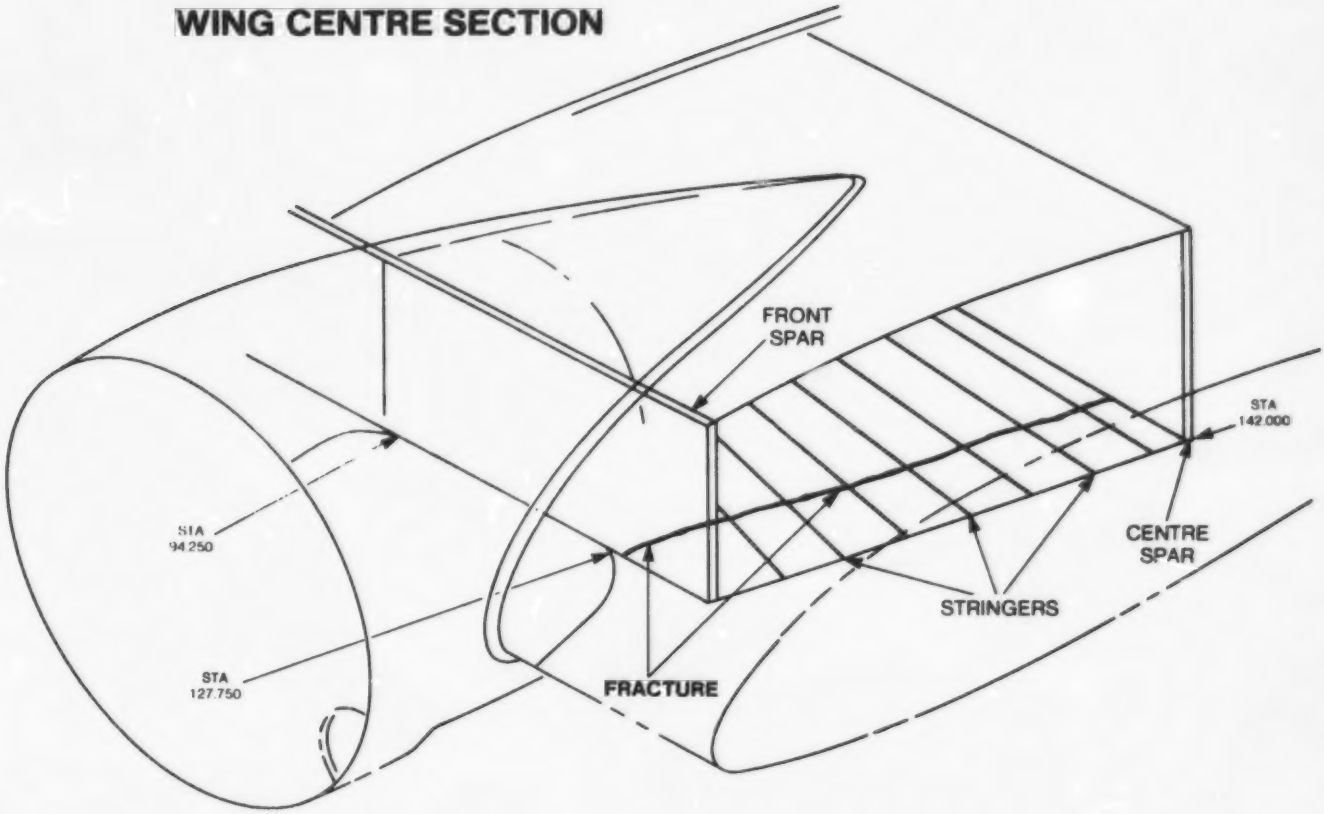
This report and the safety action therein has been adopted by the Chairman, K.J. Thorneycroft, and Board Members:

N. Bobbitt
L. Filotas
W. MacEachern
A. Portelance
R. Stevenson
F. Thurston

AREA MAP AND FLIGHT PATH


CRASH SITE
N
C-FQBU: A Twin Otter whose flight crew saw C-FADD in the holding pattern and then proceed outbound for the NDB approach. They also saw C-FADD with the failed wing prior to the crash.
C-FADD PROCEDURE TURN 1756:58
C-FQBU CIRCUIT PATTERN
C-FQBU SEES C-FADD WITH WING FOLDED 1759:48
AIRFIELD
NDB APPROACH PATTERN 120K GROUND SPEED
AIRCRAFT MANOEUVRES FROM INBOUND TRACK OF APPROACH PROCEDURE TO CRASH SITE UNKNOWN
NON-DIRECTIONAL BEACON (NDB)
C-FADD HOLDING PATTERN
PICKLE LAKE
KENORA DISTRICT
ONTARIO
Miles 1 0 1 2
Scale 1:50,000

WING CENTRE SECTION



The fracture of the bottom skin extended from the front spar in the vicinity of station 127.750, aft through to the centre spar, a distance of approximately 35 inches. The crack line approximately followed the inboard rib flange rivet line. Centre section wing stringers numbers 58 to 65 were also fractured in this area. The separation line then travelled outboard to the attachment angle at wing station 142.0 through overload shearing of the centre spar and lower skin fasteners. The centre section attachment angle doublers between the centre and rear spars then failed along the inboard most rivet line where the doublers connect to the attachment angle. Bottom skin failure of the trailing edge assembly completed the bottom surface failure. The wing upper skin, from the leading edge to the rear spar, failed in overload bending and tearing. The wing attachment bolts on the trailing edge assembly failed in tension.

WING FRACTURE

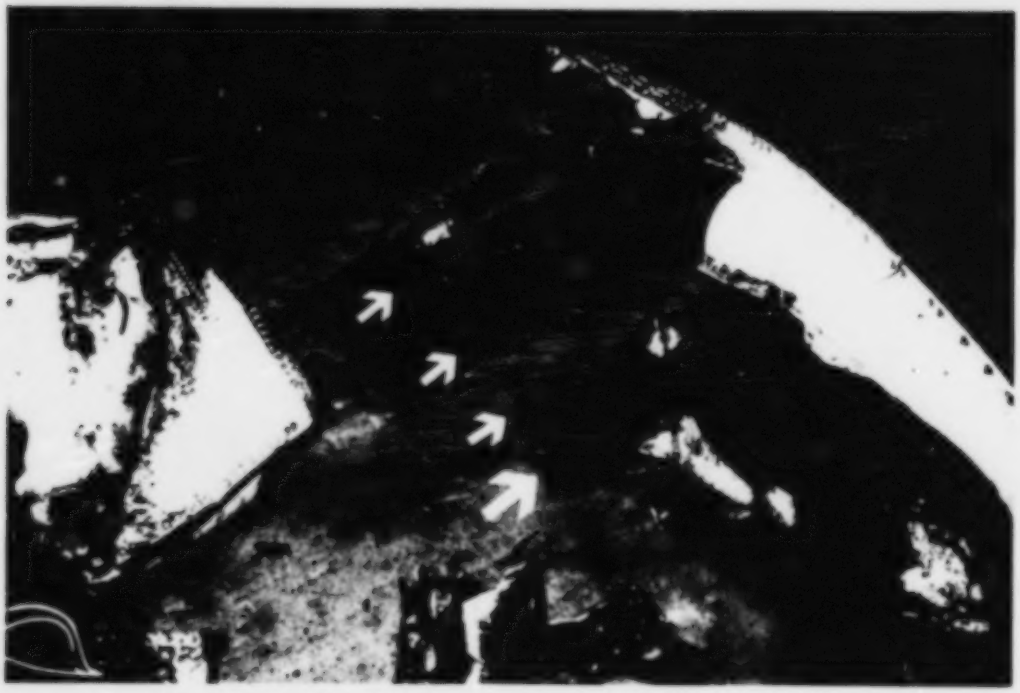


Figure 1 - Pieces of left side wing centre section. Station 127.750 indicated by large arrow. Wing separation fractured path indicated by small arrow.

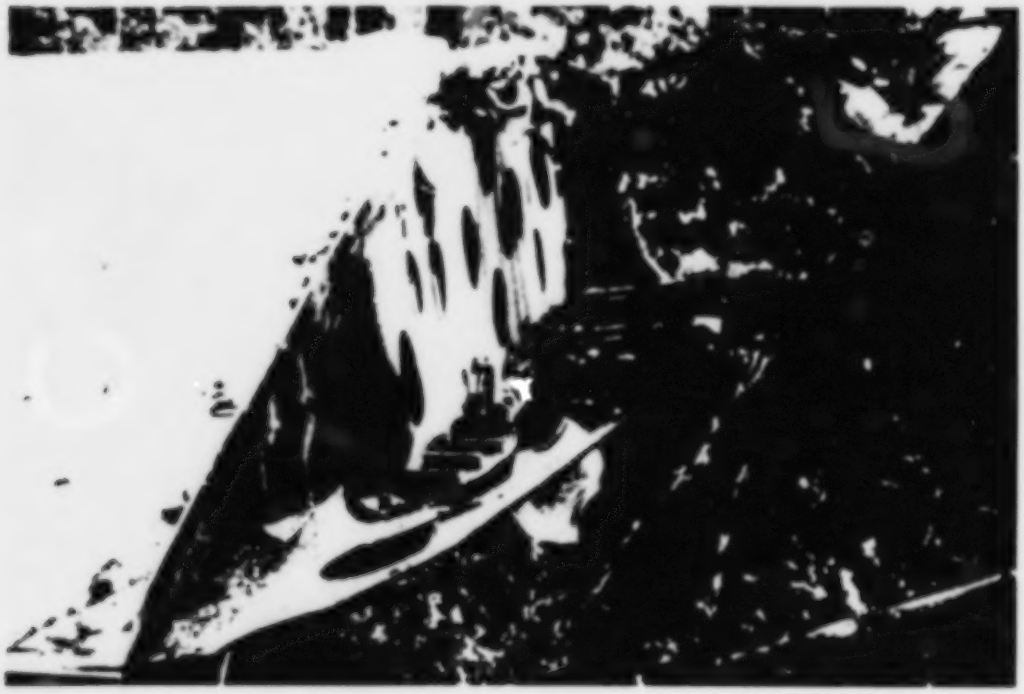


Figure 2 - Left-hand wing at accident site showing line of separation.

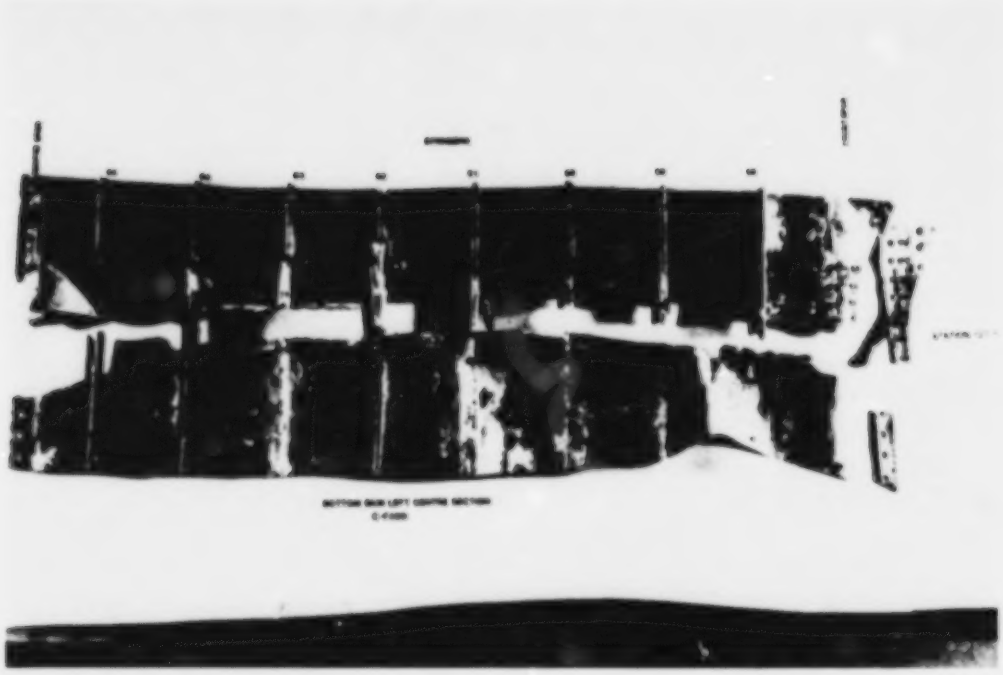


Figure 3 - Sections of lower centre wing containing mating fractures, failed stringers 58 to 65, and the fractured front spar strap.

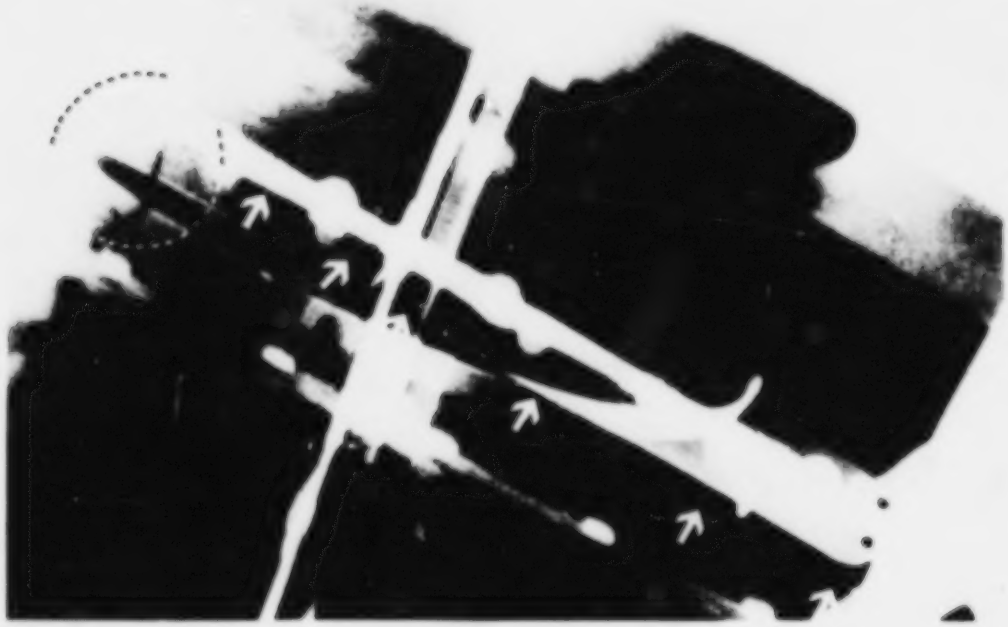


Figure 4 - P4 radiograph showing large crack indication in bottom skin along inboard rib flange (arrows). Radiograph reported taken January 1986.

LABORATORY REPORTS

The following laboratory reports were completed:

LP 99/87 - Exhaust Stack Analysis
LP 98/87 - Wing Failure Analysis

These reports are available on request from the Canadian Aviation Safety Board.

GLOSSARY

agl	above ground level
AD	Airworthiness Directive
AME	aircraft maintenance engineer
asl	above sea level
A/S	Aircraft Structures
CASB	Canadian Aviation Safety Board
CDT	central daylight time
CGSB	Canadian General Standards Board
EMR	Department of Energy, Mines and Resourses
hr	hour (s)
lat	latitude
lb	pound (s)
long	longitude
N	north
NDB	non-directional beacon
NDT	non-destructive testing
SB 263	Service Bulletin 263
UTC	Coordinated Universal Time
VFR	visual flight rules
VHF	very high frequency
W	west
°	degree (s)
'	minute (s)